Section 4
Hydraulic Model Development

4.1 Introduction

This section provides a description of the methodology used to develop the hydraulic model for the Stevens Creek Watershed. The hydraulic modeling was performed using the Army Corps of Engineer's (USACE) Hydrologic Engineering Center's (HEC) River Analysis System program (HEC-RAS) Version 3.1.1 steady state option. Both an existing and future conditions model was developed. The following appendix sections, located in Volume II of this report, provide detailed information on the hydrologic and hydraulic model data input and results:

- Appendix C - Hydrologic Model Input Data and Results
- Appendix D - Hydraulic Model Input Data and Results
- Appendix E - Stream Profiles
- Appendix J - Drainage Structure Design Data

4.2 HEC-RAS Model Development

The HEC-RAS data requirements are categorized into 10 data sets as shown in Table 4-1. The model parameters were developed using a combination of manual procedures and automation tools using ArcInfo, ArcView GIS, and HEC-GeoRAS in conjunction with GIS data. All GIS data were in Lincoln/Lancaster County projection.

Table 4-1
HEC-RAS Model Data Sets

HEC-RAS Model Parameter	Development Method	Data Requirements
Stream network	ArcView GIS	Stream centerline coverage with unique stream reach names
Cross sections (river station and geometry data)	ArcInfo and HEC-GeoRAS	Triangular irregular network (TIN), cross section cut line coverage
Downstream reach lengths (channel and overbanks)	ArcInfo and HEC-GeoRAS	Stream centerline and overbank (left and right) flow path coverage
Manning's n-values	ArcInfo	Mannings n-value coverage created from orthophotos and future development plans
Roadway crossings	Manually input using field survey data	Roadway profile and bridge or culvert opening
Dams	Manually input using field survey data	Control structure dimensions and embankment profile
Expansion and contraction coefficients	Manually input using standard values and engineering judgment	Contours and cross section cut line coverage
Normal depth boundary conditions	ArcView GIS	Contours, stream centerline, and cross section cut line coverage
Ineffective flow areas	Manually input using standard procedures and engineering judgment	Contours and cross section cut line coverages
Channel bank stations	Manually input using standard procedures and engineering judgment	Cross section geometries (station and elevation data)

A separate HEC-RAS model was developed for the main channel, each tributary, and the overflow channel. The paragraphs below describe the HEC-RAS model development procedures.

4.2.1 Stream Network, Cross Sections, and Reach Lengths

The first step in developing the HEC-RAS model was to create a HEC-RAS geometry file containing the stream network, cross section river stations and geometries, and channel and overbank downstream reach lengths. The stream network defines the extent of the model and can be defined as the main channel and its tributaries that receive runoff from areas approximately 150 acres in size and greater. Cross section river stations define the location of the cross section along the stream in miles measured from the confluence with Salt Creek, and cross section geometry includes station and elevation data. Downstream reach lengths define the distance to the next downstream cross section along the stream reach and the along the left and right overbanks.

Automation tools were used to develop the model input data described above, including HEC-GeoRAS Version 1.0 in conjunction with ArcInfo Version 7.3 and ArcView GIS Version 3.3. These tools were used to prepare an ASCII text file that was directly imported into the HEC-RAS model, creating a geospatially referenced HEC-RAS geometry file. HEC-GeoRAS is a free software program developed by the USACE HEC.

HEC-GeoRAS uses the following data to create the ASCII text import file:
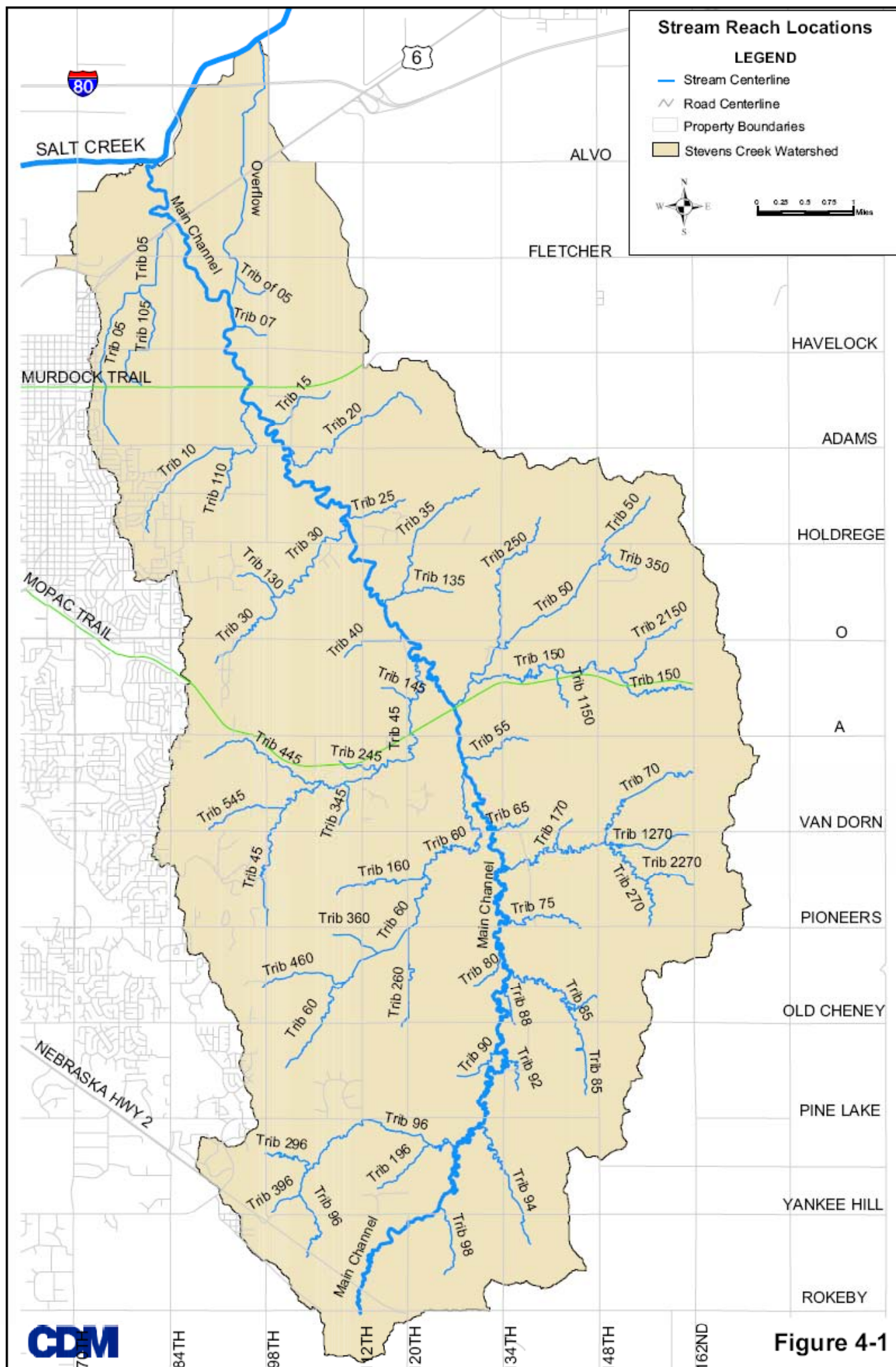
Triangular Irregular Network (TIN)

As discussed in Section 2, a TIN was created from the Lincoln/Lancaster County contour information using ArcInfo in conjunction with LiDAR. A TIN is a surface representing the ground topography and is used in conjunction with the cross section cut line coverage to develop station and elevation information for cross section geometry data. A surface elevation was recorded at each station along the cross section cut line that crosses the TIN edge.

Stream Centerline Coverage

The stream centerline coverage was created in ArcView GIS using the existing Lincoln/Lancaster County hydrography GIS coverage. The stream centerline coverage represents the Stevens Creek stream network, which includes a separate line segment for the main channel, overflow channel, and each of the 51 tributaries. HEC-GeoRAS requires a river name and reach name be assigned to each line segment. For the purpose of this study, each segment was assigned Stevens Creek as the river name. Figure 4-1 shows the location of each stream and its associated reach name.

Cross Section Coverage

The cross section coverage is a GIS line coverage that identifies the location and extent of each cross section. The cross section coverage was generated in ArcView GIS. Cross section cut lines were located along the stream centerline at points that represent the average geometry of the stream reach, and at changes in geometry, slope, channel, overbank roughness, and discharge. Available aerial photographs and contour information were used to layout the cross section locations. The FEMA 500-year floodplain boundary was used as a guide in determining the extent of the cross sections. The average distance between cross sections was approximately 400 feet, with less distance between cross sections in the vicinity of structures and abrupt changes in channel geometry.

Stream Reach Locations

LEGEND
- Stream Centerline
- Road Centerline
- Property Boundaries
- Stevens Creek Watershed

Figure 4-1

The cross sections are oriented from left to right looking downstream. Each cross section is identified by the stream name, reach name, and river station. The river station for each cross section is the cumulative distance in miles to the confluence of Salt Creek.

Overbank Flow Path Coverage

The overbank flow path coverage is a GIS line coverage that represents the average left and right overbank flow paths between each cross section. The overbank flow path coverage was used to determine the downstream reach lengths for the left and right overbanks. The FEMA 500-year floodplain boundary and the contour information were used as guides to locate the overbank flow paths. In general, the overbank flow path was located on each side of the stream halfway between the 500-year floodplain boundary and the channel bank. In areas with no existing floodplain, the location of the overbank flow path was estimated based on the width of the nearest floodplain.

4.2.2 Manning's n-Values

The Manning's n-values at each cross section were estimated using digital aerial and field photographs. A polygon coverage was created using ArcView GIS to represent land surface characteristics and the associated n-values. These values are shown in Table 4-2.

The initial n-values were used as a model starting point and were adjusted within the provided ranges during calibration. The horizontal extent of each type of land cover and the associated n-value for each cross section were determined by intersecting the land surface coverage with the cross section coverage. Multiple n-values across the cross section were imported using a customized ArcInfo tool that generates the data in HEC-RAS ASCII format.

Table 4-2
Land Surface Characteristics and Associated Manning's n-Values[1]

Land Surface Type	Initial n-Value	Range of n-Value
Grass, urban and maintained	0.030	0.025–0.035
Trees and brush	0.090	0.035–0.160
Brush	0.060	0.035–0.160
Residential areas[2]	0.150	0.035–10
ADF Plant - (developed area)[2]	0.100	0.035–10
Agricultural, Pasture	0.035	0.025–0.050
Pavement	0.020	0.013–0.025
Lake	0.025	0.0160–0.033

1 Source: Open Channel Hydraulics, Chow 1959.
2 These n-values will be used in developed areas to account for the loss of conveyance caused by buildings.

The n-values were increased where buildings are located within the floodplain to account for conveyance loss. The n-values in these areas may range from 0.030 for areas with few buildings to 0.15 for fully developed areas. If significant blockage is caused by buildings in the flood fringe, the developed areas were modeled as ineffective flow.

Channel n-values were manually adjusted using the HEC-RAS cross section data editor. A combination of digital aerial photos, field photographs, and site visits were used to select an appropriate n-value. Table 4-3 lists channel descriptions and associated ranges of n-values that were used for Stevens Creek.

4.2.3 Roadway Crossings and Dams

Bridge and culvert openings and roadway profiles were developed from data collected during field surveys. Field data were collected based on monument and GPS controls using standard field survey collection forms. These data were manually entered into the HEC-RAS model.

Table 4-3
Channel Descriptions and
Associated Manning's n-Values[1]

Channel Description	Initial n-Value	Range of n-Value
Clean, straight	0.030	0.025 - 0.033
Straight channels, weeds	0.035	0.030 - 0.040
Clean, meandering	0.040	0.033 - 0.045
Meandering, weedy	0.045	0.045 - 0.050
Sluggish, weedy	0.070	0.050 - 0.080
Very weedy, floodways with heavy timber and underbrush	0.100	0.075 - 0.150

1 Source: Open Channel Hydraulics, Chow 1959

HEC-RAS requires four cross sections to be entered to define each drainage structure. The four cross sections include a downstream cross section where flow is fully expanded, a cross section at the downstream face of the structure, a cross section at the upstream face of the structure, and an upstream cross section prior to flow contraction. Three cross sections were cut from the TIN to model each hydraulic structure. These three cross sections include the downstream cross section at fully expanded flow, the upstream face, and the upstream cross section prior to flow contraction. The upstream face cross section was copied downstream to represent the downstream face.

The flow lengths between the bridge cross sections and the upstream and downstream cross sections were determined using ArcView GIS. The drainage structure location in river miles was estimated by intersecting the stream network coverage with the roadway coverage. A unique identifier was given to each structure for ease in identification. In instances where County IDs have been assigned to structures, the County ID was documented in the cross section description in the HEC-RAS model.

4.2.4 Expansion and Contraction Coefficients

The expansion and contraction coefficients were estimated based on the ratio of expansion and contraction of the effective flow area in the floodplain occurring at cross sections and at roadway crossings. Typical coefficients used in the model are listed in Table 4-4. The expansion and contraction coefficients were manually coded into the HEC-RAS cross section data editor.

Table 4-4
Expansion and
Contraction Coefficients[1]

Transition Type	Expansion Coefficient	Contraction Coefficient
Gradual	0.3	0.1
Roadway Crossing	0.5	0.3
Abrupt	0.8	0.6

1 Data from HEC-RAS Hydraulic Manual, Page 3-20

4.2.5 Boundary Conditions

Normal depth was used as the downstream boundary condition for all modeled reaches. This boundary condition requires the input of the energy grade line (EGL) slope at the downstream boundary of each reach. The downstream EGL slope can be approximated as the channel invert slope from the contour data. Therefore, the slope between the two most downstream cross sections was used to calculate the normal depth boundary condition for each reach. This slope was calculated in ArcView GIS using the elevation contour data, cross section

cut line coverage, and stream centerline coverage. For the main channel, the normal depth was calculated in ArcView GIS using the thalweg survey, cross section cut line coverage, and stream centerline coverage.

4.2.6 Ineffective Flow Areas

Ineffective flow areas were determined using the cross section plots and contour information. The following situations required the use of the ineffective flow area option:

- Floodplain areas significantly below the top of the channel bank that are not hydraulically connected to the channel downstream.
- Floodplain areas within the hydraulic shadow of roadway encroachments caused by contraction and expansion of flow through the bridge or culvert openings. These were estimated using 4:1 expansion and 1:1 contraction ratios.
- Floodplain areas within the hydraulic shadow of other obstructions or irregularities in the stream valley floodplain.
- Floodplain areas that are significantly blocked by buildings.

Ineffective flow areas were manually coded into the HEC-RAS cross section data editor.

4.2.7 Channel Bank Stations

The bank stations were located and entered manually by graphically editing the cross sections within HEC-RAS. The bank stations were verified by comparing samples of channel bank stations from the field survey, the GIS generated cross section geometries, and conditions during field reconnaissance.

4.3 Special Modeling Cases

During the development of the HEC-RAS model, unique hydraulic situations were encountered that required supplemental calculations as described below.

4.3.1 Stevens Creek Overflow Channel

Two flow diversions occur along the Stevens Creek main channel between Highway 6 and Fletcher Avenue, and one diversion exists along Tributary 5. As described in Section 3.2.7, the HEC-HMS and HEC-RAS models were used to develop the appropriate flow diversions between the primary and overflow channel. At locations where the flow is within both the primary and overflow channel, cross sections were truncated in both models at the ridge to avoid double counting channel conveyance.

4.3.2 Split Flow Occurrences

On the western side of the watershed, the stream at times drains parallel to the roadway before draining into the roadway culvert crossings. During flooding conditions, if the roadway profile is low enough, flow can be released across the road creating a split flow situation. This occurs at two locations during flooding conditions:

- Upstream of drainage structure SC180 (8' x 5.5' RCB, tributary 40) along Highway 34

■ Immediately upstream of drainage structure SC290 (twin 8' x 3' RCB, tributary 45) along 98th Street

For these two cases, spreadsheet calculations were used to estimate the amount of flow released across the roadway, referred to as split flow. For both cases, the split flow was subtracted from the primary channel, which resulted in a reduced flow rate at each drainage structure. At the next cross section downstream from the culverts, the split flow was added back to the primary channel flow rate.

4.4 Floodway Determination

A floodway was determined for each of the modeled reaches. The floodway is determined from the floodplain model by encroaching the left and right overbanks of each cross section to produce a target rise in water surface elevation. The encroachments simulate fill within the floodplain that reduces conveyance of flood flows.

A 1-foot rise criterion was used to determine the encroachment stations at each cross section. Initially, Encroachment Method 4 was used to estimate encroachment stations at each cross section. Encroachment Method 4 automates the floodway modeling process by computing the encroachment station so that conveyance within the encroached cross section (with a target water level) is equal to the conveyance of the natural cross section at the natural water level. The higher water level for the encroached cross section is specified as a fixed amount above the natural profile. A target increase of 1.0 foot was used for this analysis.

Once the initial encroachment stations were determined by HEC-RAS using Encroachment Method 4, each cross section was reviewed and adjusted if necessary to meet the target 1-foot rise. The downstream boundary condition for the floodway model was set at 1.0 foot above the 100-year water surface elevation.

4.5 Model Verification

The HEC-RAS model was verified by comparing the results to existing FEMA floodplain maps, historical high water marks, and aerial photos showing past flooding. For example, the June 1984 flood event caused a significant amount of building damage along Highway 6. During this flood event, the owners reported that the Telex building had 14 inches of floodwater in the main building, which equates to flood elevation of approximately 1,135.60 feet. In 1984, no NRD farm ponds were constructed. In comparison, the study HEC-RAS 100-year flood elevation under existing land use conditions is approximately 1,135.00 feet. Five NRD farm ponds were simulated under existing conditions, which may account for the slightly lower flood elevation at the Telex building location as estimated by the HEC-RAS model. In addition, information obtained from public meetings and questionnaires were used to verify the model results.